

A Neutrino Physics Program for a Kiloton Scale Neutrino Detector at Boulby

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It has been shown by KamLAND that long-distance monitoring of an ensemble of reactors is possible using a one-kiloton Liquid Scintillator (LS) detector [1]. In addition, the development of very large (megaton scale) water Cherenkov detectors is underway for future long-baseline neutrino experiments (e.g. Hyper-Kamiokande) [2,3]. Thus, given the success of small (few tons) neutrino detectors to passively obtain detailed information on the operation of commercial reactors [4], it has become a goal of the Nuclear Non-Proliferation (NNP) community to demonstrate the potential for water-based megaton-scale neutrino detectors for long-range monitoring. A collaboration of U.S. universities and laboratories (a.k.a. WATCHMAN) is now conducting a DOE-sponsored site search for a kiloton scale advanced water detector demonstration. The goal is to show that the backgrounds and efficiencies can be controlled to a level sufficient to proceed to the realization of long-range monitoring. WATCHMAN is focused on deployment at a US reactor. However, here we note that the Boulby Underground Laboratory is an exciting candidate site. Boulby sits at a depth of ~ 4000 m.w.e. twenty-five kilometers from the (2×1.575 GW_{th}) Hartlepool Nuclear Power Station. Choice of this site would allow additional fundamental physics goals to be realized, via an upgrade to the baseline WATCHMAN detector. At this distance, a two-kton LS detector would detect ~ 4.6 events/day assuming 100% efficiency. For a LS detector, a 90% efficiency and 3% resolution at 1 MeV are possible with existing high light yield LS and 3-4 times the typical 15-20% light coverage of existing reactor experiments. Thus there can be a two-phase science program in parallel to the NNP demonstration project: (i) a program using the Gd-doped (and possibly water based LS (WbLS)-doped) water Cherenkov (WC) detector, and (ii) a program with a high resolution LS fill using the same facility after the demonstration is concluded.

In the second phase, a kiloton scale LS detector would be very sensitive to θ_{12} , as unlike KamLAND there is only a single distance involved (no other nearby reactors). This sensitivity would be further enhanced due to lower energy threshold and better resolution offered by a LS detector designed for low WC light levels. Figure 1 shows: (i) the “no oscillation” (solid) versus “oscillation” (dashed) Evis spectrum, (ii) the disappearance fraction for neutrinos in the LS phase (left) and water phase (right). This represents 20 kton-years exposure, 3% resolution for LS and 20% resolution for WC (plus loss of light due to the Cherenkov threshold). Error bars are statistical. Studies are underway to determine how precise such a measurement could be in both phases, and also how large an exposure would be needed to determine the neutrino mass hierarchy. This is possible because the small wiggles in the oscillated spectrum are different for NORMAL and INVERTED hierarchy.

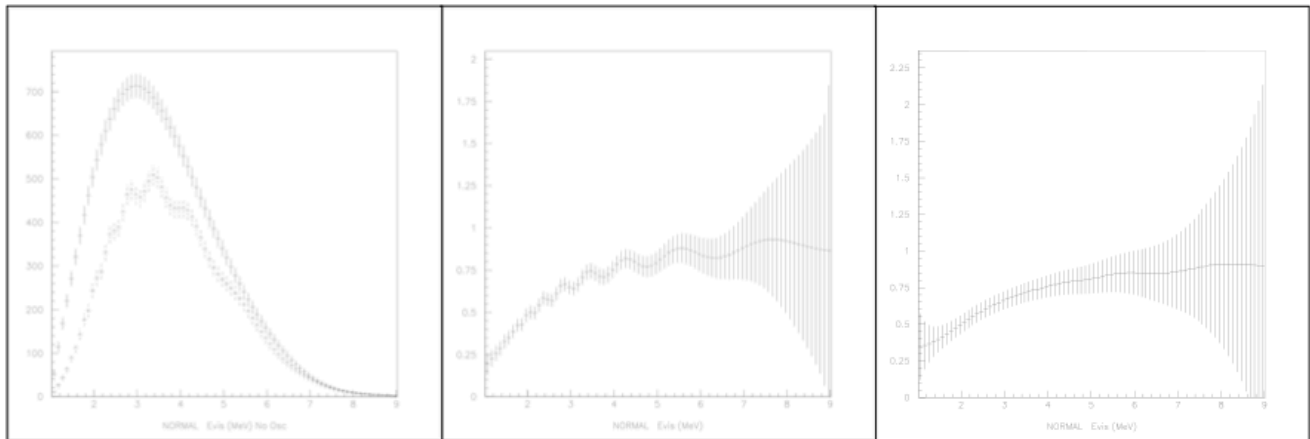


Figure 1 Smeared Evis Spectra and ratio for LS and WC

In addition to reactor neutrino physics, this detector would be sensitive to a Galactic Supernova, detecting roughly ~ 100 events/kton for a burst at the galactic center, independent of the LS or WC fill. During the LS phase, this would also be an excellent geo-neutrino detector for exploring another geophysical region of the world. Finally, this detector would be an excellent test bed for future large WC experiments to explore possible WbLS and Gd-doping, plus allow for testing of large area MCP's and compact accelerators, which not have important physics applications but are also have significant commercial uses.

References:

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